SCIENCE FOR GLASS PRODUCTION

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STUDY OF THE STRUCTURE OF FOAM GLASS WITH DIFFERENT CHARACTERISTICS

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The results of a study of the micro- and macroscopic structure of foam glass with different characteristics are reported.

Due to the increase in the cost of energy carriers and stiffening of the standards on energy consumption, the rational use of thermal and other energy resources has recently been stimulating special interest. According to SNiP 2.01.01–82, the adjusted heat transfer resistance for the central region in Russia should be a minimum of 3 $m^2 \cdot K/W$, which corresponds to approximately 1 m of thickness for a brick wall. Using heat-insulating materials both in construction and for thermal insulation of industrial objects significantly increases the efficiency of utilizing thermal energy and reducing consumption of construction materials [1 – 3].

Modern industry manufactures a relatively large amount of different heat-insulating materials: mineral wool, expanded perlite, cellular concretes, heat-insulating plastics, foam glass.

Foam glass has a unique set of properties (incombustibility, refractoriness, temperature stability, etc.) and is the most appropriate heat-insulating material for long-term use in construction. The relatively high maximum temperature of use of foam glass allows using it as external heat insulation for industrial furnaces for different applications. The relatively high (in comparison to materials with similar thermal conductivity) strength ensures the longevity and versatile use of construction structures.

Foam glass production technology at present has been insufficiently worked out and has many “blank spots.” On one hand, the glass matrix, whose properties during production (high-temperature heat treatment) are essentially a function of the thermal history of the material, the crystallizability of the melt, and the effect of foaming agent impurities on it, is the base of foam glass. This undoubtedly places important restrictions on the heat treatment conditions and unambiguously affects the strength properties of the finished article. On the other hand, the highly porous structure of heat-insulating material changes the stress-strain state of an article during production and use to a significant degree.

Since effective heat-insulating material contains a large amount of gas phase — up to 96% (see Table 1), the pore size and character of the pore volume distribution play a fundamental role in organizing a rational structure. Regardless

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TABLE 1

Sample No.*	Foaming temperature, °C	Foaming agent	Mass content, %	Density, kg/m^3	Compressive strength, MPa	Porosity, %	Average pore size, mm
1	910	Chalk	2.5	373	2.7	85.0	1.05
2	910	″	2.5	340	2.9	86.4	1.15
3	910	″	2.5	152	1.9	94.0	3.10
4**		No data		100	1.1	96.0	0.58
5	910	Chalk	2.5	241	2.7	90.0	1.36
6	790	Carbon, carbon black	0.9	210	2.0	92.0	0.82
7	910	Chalk	2.5	395	2.1	84.0	No data
8	900	Carbon black	0.2	329	3.1	86.7	0.19
9	910	Chalk	2.5	238	2.2	90.5	0.30

* In all cases, the specific surface area of the batch was 400 m^2/kg.

** Sample from Foamglass Co.

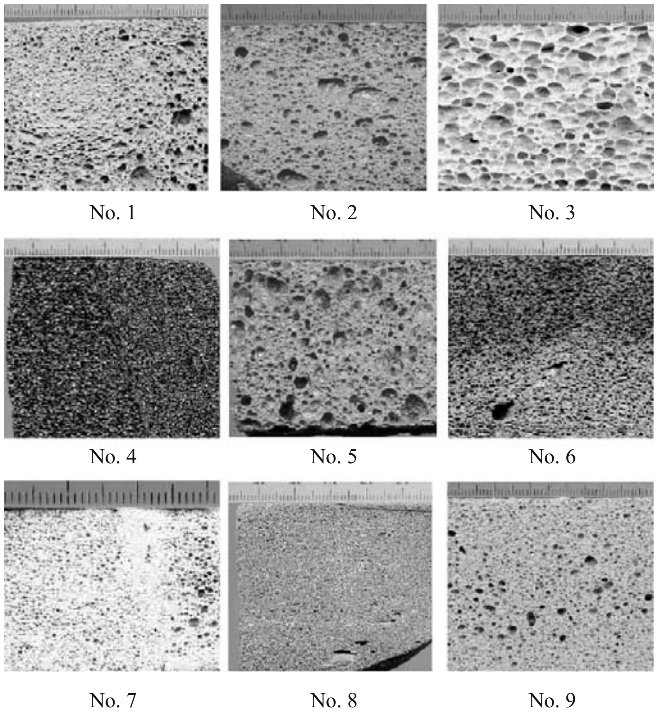

Fig. 1. Samples of foam glass of different structure.

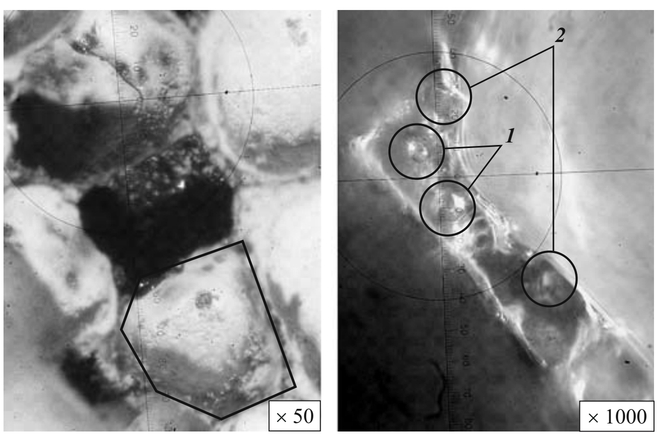

Fig. 2. Microstructure of foam glass in reflected light: *1*) micropores; *2*) foreign inclusions.

of the method of preparation, foam glass has an inhomogeneous type of pore volume distribution. This is especially marked in sample No. 3 (Fig. 1) with a large average pore size. The large pores are surrounded by medium and small pores, and the amount and density of glass melt per unit of volume of foam glass naturally decrease. This is probably due to the foaming process, where the gas phase is redistributed toward a decrease in its thickness over the volume of the material in accordance with the pressure inside the bubbles and the surface tension of the glass melt.

On the other hand, the smaller the average pore size, the more homogeneous the structure of the foam glass, which is especially marked in samples Nos. 4, 7, and 8. We do not know how this affects the properties of the foam glass, but at present we can say that the pore distribution in foam glass has a structure close to hexagonal with inclusion of pores of different size. In conditions of × 50 magnification, this conclusion is confirmed: the pores are actually not circular, but close to hexahedral (Fig. 2).

In examining the walls between pores, we note that the foam glass matrix has an inhomogeneous structure containing micropores and foreign inclusions (probably glass batch fragments). Partial crystallization of the surface) can be hypothesized along the perimeter of the wall (because of the change in the reflection favor).

Crystallization of foam glass can be examined in more detail in transmitted light in the section of sample No. 7 (Fig. 3). The important brittleness and thinness of the foam glass matrix do not allow obtaining a high-quality section of the sample, but after elimination of noise and additional image processing, we can see that the microstructure of the foam glass is far from homogeneous (this is especially marked at high magnification).

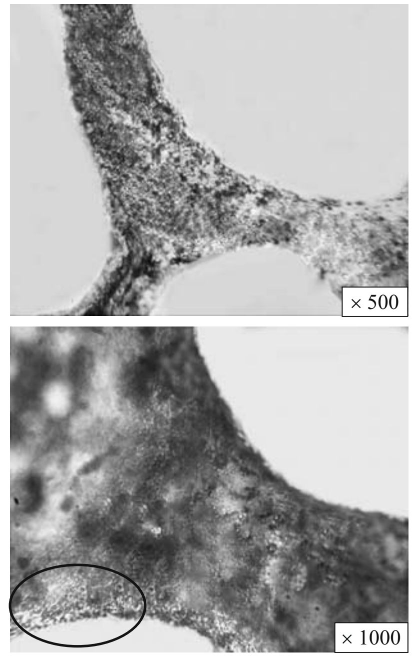

Fig. 3. Microstructure of foam glass in transmitted light.

The study of the photomicrographs of the samples of foam glass thus showed that:

the sections of the pores in foam glass have a shape close to hexahedral and are not round (as in most models that describe the structure of a porous body);

the matrix of foam glass has an inhomogeneous structure containing micropores and foreign inclusions;

the glass melt is partially crystallized on the surface of the matrix.

Crystallization of foam glass can be determined in more detail by x-ray phase analysis.

Based on the results of XPA, we can say that in addition to an amorphous phase, the structure of foam glass contains crystalline inclusions of different chemical composition. The quantitative content of the crystalline phase is not only determined by the chemical composition of the glass, but also by the type of foaming agent (Samples Nos. 6 and 8). The composition and quantitative phase ratio can vary significantly as a function of a multitude of parameters, so that studying the general characteristics of the stress-strain state of the structure of foam glass is very complicated.

A relatively large amount of crystalline phase was found as a result of the x-ray phase analysis of the samples. The amount and chemical composition of this phase varied significantly in the different samples (even in samples with the same glass composition).

The variety of foreign inclusions in the structure of foam glass and lack of effective methods of evaluating stresses in highly porous materials did not allow obtaining reliable data on the stress-strain state of these samples. Constructing a mathematical model of highly porous substances (in the given case, foam glass) is the simplest way out of this complicated situation.

REFERENCES

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